VOLUME XVIII NUMBER 5 WHOLE NUMBER 139

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS
J. S. PLASKETT
Director of the Dominion Astrophysical Observatory, Victoria, B.C.

SIR FREDERIC STUPART
Director of the Meteorological Service of Canada, Toronto

PUBLISHED MONTHLY
(*Ten numbers per year*)

May, 1924

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

FOREIGN AGENTS: WHELDON & WESLEY LTD.
2-4 ARTHUR STREET, NEW OXFORD STREET, LONDON, W.C. 2

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA

VOL. XVIII, No. 5 MAY, 1924 WHOLE NO. 139

Articles PAGE

James B. McDowell: an Appreciation - - *J. S. Plaskett* 185
Mercury, as an Evening Star (Sonnet) - - - *John Dale* 194
Ad Astra (Sonnet) - - - - - - - *J. E. Wetherell* 194
The Summer Sky - - - - - - *A. Vibert Douglas* 195
The 1924 Transit of Mercury - - - - - *A. R. Hassard* 199
The Applications of Modern Physics to Astronomy (*Continued*) - - - - - *H. F. Balmer* 201

Review of Publications - - - - - - - - - - - 224

Notes and Queries - - - - - - - - - - - - 226

Meetings of the Society - - - - - - - - - - - 229

Upon request, made previous to publication of article, contributors will be supplied free either with fifty copies of the issue containing the article, or with the sheets containing the article stitched in a printed cover. If separate reprints are desired the cost will be as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies	$3 50	$6 50	$ 9 50	$10 00	$13 00	$16 00
100 copies	4 00	7 00	10 00	11 00	14 00	18 00
200 copies	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Business correspondence, remittances, etc., should be addressed to H. W. Barker, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

PLATE IV

Charles S. Hastings (left) and James B. McDowell

PLATE V

Mr. McDowell at work on the 30-inch Alleghany Objective

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XVIII MAY No. 5

JAMES B. McDOWELL

AN APPRECIATION

By J. S. PLASKETT

THE sudden death of J. B. McDowell, familiarly called "Jimmy," came to all his friends, and they were many, as a great shock and with a deep sense of personal loss. Mr. McDowell was so vigorous, so active and so full of life and energy that it is difficult for those of us who knew him intimately to realize that his sterling characteristics and his genius as an optician are lost to the world.

James B. McDowell was born on Dec. 2, 1860, in County Down, Ireland, and was the son of James and Katherine Sloane McDowell. He, with his mother and sisters, came to America in May, 1867, settling in Pittsburgh and making their home on the South Side. At an early age he commenced work with Brice Bros., glass makers, and worked there till 1882. On March 25, 1880, he married Effie Afton Brashear, adopted daughter of John A. Brashear, who survives him, although their two sons are both dead. Shortly after his marriage, he started working in the evenings in the little optical workshop owned by his father-in-law. He soon developed such great skill in handling and figuring optical surfaces, that he gave up his work with Brice Bros. and devoted all his time to the making of mirrors, lenses and other optical accessories.

The history of the development of the optical business of the John A. Brashear Co. is a very interesting one, and many anecdotes of their early trials and experiences were told me by Dr. Brashear in my visits to Pittsburgh. Dr. Brashear, as everyone who had the privilege of knowing him admits, had a unique and most charming personality, made hosts of friends everywhere, and was held as the best loved citizen not only of Pittsburgh but of the whole state of Pennsylvania. He had so many outside educational and philanthropic interests and was in such great demand for lectures and addresses, however, that the optical work of the firm fell more and more upon the son-in-law "Jimmy", who accepted it with enthusiasm and soon became a master of the art.

No one was more insistent than Dr. Brashear himself that Mr. McDowell was the real optician of the firm, but the modesty of the latter and his entire lack of self advertisement, coupled with the fact that the firm name was Brashear, that Dr. Brashear attended to all the correspondence, that he was the representative of the firm at all scientific and other meetings, made it inevitable that most of McDowell's optical work was generally credited to Brashear. Probably only a few of the many customers of the Brashear Co. realized that the beautiful quality of their optical instruments was due to the skill, not of the head of the firm but of his son-in-law and partner. No one, I am sure, would rejoice more than Dr. Brashear himself to have this misapprehension corrected and justice done to the incomparable optical skill of Jas. B. McDowell.

It is not the purpose of this sketch to attempt a catalogue of the many optical achievements of Mr. McDowell but rather to give a short account of my association with him and of the work done for us, in the hope that it may convey some idea of his skill as an optician and of his sterling characteristics as a man. Prior to my first dealings with the firm in 1903, and before I knew either Brashear or McDowell personally, their reputation as opticians was already firmly established and they had several fine objectives to their credit. The 15-inch Ottawa objective, completed some years before I joined the Dominion Observatory and tested by me by the Hartmann method, fell in the "hervorragende gute" class. The only

other large earlier objective figured by Mr. McDowell of which I have any special knowledge was an 18-inch, used for a time by Percival Lowell but eventually purchased by the University of Pennsylvania and mounted in the Flower Observatory. Mr. McDowell was justly proud of the quality of this objective for, even in the comparatively poor seeing of Philadelphia, it divided doubles to its full theoretical resolving power and with it Eric Doolittle carried out his magnificient work on double stars.

My first intimate association with Mr. McDowell was in the figuring of a new correcting lens for the 15-inch telescope. This was a difficult and unusual optical process, for to compensate for the chromatic difference of spherical aberration of the 15-inch objective required the insertion of the exactly opposite amount of aberration in the correcting lens. The 15-inch could not conveniently be taken to Pittsburgh and this entailed my taking the corrector there, after the combined aberration had been measured at Ottawa, and testing it with an auxiliary image forming lens. It was in this process that I first really appreciated Mr. McDowell's remarkable skill in handling optical surfaces and his ability to remove or insert spherical aberration to any desired amount in the figuring process. It was at this time also that I got a real insight into the sterling character, the kindly and humorous nature of the man, and that our long friendship began. He would always claim that he was the hard-headed business man of the concern and that all the idealism was confined to Dr. Brashear. But he himself was an idealist of the highest type so far as an optical surface was concerned. I am positive he never allowed any objective, in which definition was required, to leave the shop unless it was as good as he could make it, and time and expense were neither counted nor spared where quality was concerned.

Time after time in our dealings with him this characteristic was demonstrated and even Dr. Brashear was not more scrupulous or particular about quality than Mr. McDowell, notwithstanding all the talk of the latter to the contrary. He was always ready to try any experiments promising improvement in optical performance and always loath to make any charge for such experimental work.

A considerable part of the success of the spectroscopic work at Ottawa and Victoria must be credited to the superlative quality of the lenses and prisms made by Mr. McDowell. The voluntary refigurings and other experimental work, notwithstanding his repeated statements about looking after the business end of the optical profession, were never adequately charged for. I have good reason to believe that this scrupulousness about accuracy and this reluctance to charge more than the list price for any objective, no matter how much special work there was on it, extended to other astronomers as well.

It was after my friendship with him was established that the largest objectives constructed by Mr. McDowell were undertaken. The largest lens figured by him was the 30-inch for the Allegheny Observatory, corrected for the photographic region and completed about 1916. Although no numerical results of the tests of this objective have been published, I have been assured that the figure is of unequalled quality and the splendid parallaxes obtained by this telescope form sufficient evidence of its excellence. This objective was followed shortly after by the 24-inch Swarthmore, of equally good quality, also now producing high grade parallaxes. The last two large lenses undertaken by Mr. McDowell were the 26-inch for Yale and the 27-inch for Ann Arbor, both to be placed and used in the southern hemisphere. The 26-inch was completed a few weeks before and the 27-inch was in process of figuring at the time of his death.

But it was not only in large lenses that he excelled, his record on large mirrors is unequalled. To the best of my knowledge, the first large mirror figured by him was the 37-inch for the Chile station of the Lick Observatory. This was followed by the 30-inch Allegheny, the 37½-inch Ann Arbor, the 73-inch Victoria and the 37-inch Tucson, all of which are of the highest quality and all in effective operation.

Of all these mirrors I can speak with first-hand knowledge of the 73-inch only and it seems worth while to give some details of the figuring of this, the largest optical surface undertaken by Mr. McDowell, to show the exacting nature of the operation and the

great nervous strain under which the optician works while the figuring is in process. The disc was received from the St. Gobain Co. in August, 1914, and the rough grinding and preliminary polishing were completed in about eight months. This work was mostly performed by Dr. Brashear personally, who had the greatest interest in this mirror and spent a greater portion of his time on this surface than on any other work passing through the shop in recent years.

The figuring, the final polishing which brings the surface to the correct shape, was delayed for various reasons until late in 1916. Mr. McDowell's method of obtaining the final parabolic form on large mirrors was to first brings the surface to an approximate sphere and to a true surface of revolution, no easy task in a large mirror. The second process was to "turn up" the edge, undercorrect the mirror, by a full sized polishing tool moved over the surface by a certain kind of stroke. The purpose of this undercorrecting was to enable the final parabolic curve, obtained with a sort of clover leaf, full size polisher, to be uniform and smooth from centre to edge without having the edge too much rolled back or rounded off, one of the chief dangers in making all optical surfaces.

To obtain these different forms, and to carry them to just the right degree before going on to the next stage, is an exceedingly difficult art and calls for the exercise of unlimited patience and of the highest kind of trained judgment based on long experience. But it requires even more than this, an intuitive faculty which will tell one when to depart from past experience, for no two surfaces and no two polishing tools behave alike. Indeed to be a successful optician one must have not only the scientific mind but must possess as well a sort of sixth sense, an artistic intuitive perception, often in contradiction to the dictates of experience. These faculties Mr. McDowell possessed in a superlative degree, combined with insistence on the nearest possible approach to perfection in his work, courage, and persistence under failure and disappointment.

These qualities, which made him the optician he was, were all required on the 73-inch, for the processes outlined above had to be

repeated three or four times before final success was attained. At the first attempt, the surface for some unaccountable reason became scratched, requiring the polishing out of these scratches and a repetition of the whole process. In the second attempt, I believe the edge was rolled back too much and a third start had to be made. This seemed to promise well, and I was called to Pittsburgh in the autumn of 1917 while the final stage of parabolizing by the full size leaf polisher was under way. This gave me an unequalled opportunity of estimating the genius of Mr. McDowell in his attack on the extraordinarily difficult task of bringing the whole area of 4000 square inches to an accuracy of about an eighth of a wave length of light, one four-hundred-thousandth of an inch.

The nervous tension which such exacting work induced in Mr. McDowell and his able chief assistant Mr. Fred Hageman, even also on Dr. Bashear and the writer, was shown by their inability to rest, think of anything else, or do any other work in the long waits of several hours required for the mirror to steady down before a reliable test of the result of half an hour's polishing could be made. The intervals after polishing were spent in futile testing or attempts to pass the time by solitaire or other card games. The disappointment, when after all the care, anxiety and nervous strain, the mirror was finally in a smoothing process polished too deep in the centre, was so great as to make Mr. McDowell actually ill.

Nothwithstanding this disappointment after such a close approach to completion, and the tremendous strain of pressing war orders, a fourth attempt after four months further work was finally successful, the 73-inch mirror, with an unsurpassed figure, passed all tests successfully, as recounted elsewhere, and it and the work it is doing form an enduring monument to Mr. McDowell's skill and persistence.

It is certain that the great nervous strain, which these large optical surfaces entailed, undermined his health, robust as it was, and the tension of the figuring of the 26-inch Yale, closely followed by the 27-inch Ann Arbor, was too much for even his strength, and he died suddenly in the shop on Nov. 28 last. It is very unfortunate that this sudden ending should have given rise to unfounded news-

paper reports of his suicide, which have been repeated in an item in *Science Service* about the 27-inch objective. To those of us who knew "Jimmy" McDowell at all intimately and had the privilege of being counted among his friends, it is quite inconceivable and impossible that such an inherently joyous character, a man of intense activity and love of life, should put an end to himself, and I am glad to be able to refute this slander by a statement from his widow, Mrs. McDowell, through his secretary, Miss Dick.

"Sometime previous to Mr. McDowell's death he had not been well and had worked night and day on the 26-inch objective (which had been successfully completed only a short time before), followed closely by work on the 27-inch objective. At the time he left us, he was working night and day on the 27-inch, staying in the shop at night. We believe he must have looked at the glass, possibly worked it, a few hours before his death. He no doubt came up to the office where he had a couch, with the thought of resting a few hours, then looking at the glass."

"When Mrs. McDowell found him, he was in a natural position and appeared to be sleeping. The blanket had fallen to the floor, she lifted it and covered him. After calling repeatedly, receiving no answer, thinking he was sleeping very soundly, decided to shake him, when she noticed the ashen look and his form was rigid. There was no look of pain or struggle, he just appeared to be sleeping soundly. We are quite *positive* he had fallen asleep and never awakened."

The practice of Mr. McDowell of going to and staying in the shop at nights when a big piece of work was under way, in order to test in the quiet and leisure of the night, was an old one with which even I, in my occasional visits to Pittsburgh, was familiar. Consequently there can be no room for doubt that Mr. McDowell died naturally and, as he would have preferred, in harness.

This sketch of Mr. McDowell's optical achievements is very incomplete for, in addition to his major work on astronomical objectives, refracting and reflecting, he developed in collaboration with Prof. Hastings an efficient type of large aperture-ratio, wide-field doublets for astronomical photography. Many such doublets

of ratio *f*5, from 4 inches to 16 inches aperture, were made, the most famous probably being the 10-inch Bruce used by Barnard in his wonderful photographs of the Milky Way, and the 16-inch for Max Wolf at Heidelberg. The grating plates used by Rowland and Anderson were all made at the Brashear shop and a very varied range of other optical instruments were also produced. Besides this scientific work, they did a large business and produced a tremendous quantity of smaller optical parts for range finders, gun and rifle sights, field glasses and other military equipment.

There is no doubt that, in quantity and variety of optical production and in its unexcelled quality, he was the first optician of his time, not only in America but in the world. In his life, notwithstanding his modesty and his depreciation of the value of his work, he probably did more for the advance of science, certainly of astronomy in America, than many scientists, and his death is a great and apparently irreplaceable loss to science.

He was very fond of and proficient in many kinds of sport and had a great many friends, kindred spirits in this line. But I believe his greatest friend, the man whom he admired and esteemed more than anyone else, was Professor Charles S. Hastings of Yale University, who acted as the scientific associate of the Brashear Co. and computed the optical constants of all their objectives. It was a great pleasure to hear Mr. McDowell talk of Prof. Hastings, to hear his enthusiasm about the optical and other ability and the personal qualities of his great friend. This affection and admiration for his friend, though he did not look at it in that way, was a real tribute to his own singleness and sincerity of spirit.

It is very fitting, therefore, and a striking testimony to his modesty that the only photograph Mrs. McDowell could supply me of her husband was an enlargement of a snap shot of him (right), in a very characteristic pose, and Prof. Hastings (left), taken in front of the Brashear home at 1954 Perrysville Avenue in 1918.

The other photograph is one of a stereoscopic pair made by the writer on a visit to Pittsburgh about 1910. Mr. McDowell is measuring the radius of curvature of the flint component of the 30-inch Allegheny objective in the course of the fine grinding.

I cannot do better than close this inadequate tribute to the man and optician James B. McDowell than by two quotations. The first briefly and clearly represents the feeling of his employees and is expressed at the end of a business letter from his secretary to me. "In the shop we all miss Mr. McDowell and feel we have lost the best friend ever. He was one of the finest, rather the finest man I ever knew. It is hard to think he will never be around the shop again, just seems it is impossible he is gone." The second is a quotation in the words of one of his friends, Charles M'Ateer, published in a Pittsburgh paper just after his death.

"James B. McDowell now belongs to the ages. James B. McDowell was like himself, he patterned after none, he was a genius, he put his soul in his work. He cared nothing for beaten paths, nothing for the footsteps of others. James B. McDowell had within his brain that divine fire called genius and a touch of nature that makes the whole world kin.

"In conversation he gave us quaint thoughts and sayings filled with the pert and nimble spirit of mirth; his conversation was filled with sunshine and in every word was the pulse and breath of life. . . . . James B. McDowell received from nature nature's choicest gifts. His intuitive power was all that nature had in that line to give. He was ever kind to all. He was always ready to give help to the amateur and professional alike. Let us pray our Heavenly Father to care for him as he helped and cared for others, we ask no more. For 40 years the writer knew him and he was always the same."

Victoria, B.C.,

April, 1924.

MERCURY, AS AN EVENING STAR

Shy child of Heaven! pale and afeard of Night.
  On Earth not e'en the tiniest pool but knows
  Thy face, charm-framèd in the dying rose
Of evening, and million-mirrored sprite
In dance with laughter of the wind's mild making.
  Thou faery nursling of the Sire of Day!
  (He who in playful plot with smiling May
Late garlanded the drowsy Earth; she, waking
  But to the matin-cry of yester-dawn,
Found her white cover drawn, half-drest in bloom.)
  Ah! while my gloating eyes dim, thou art gone.

  —And now the Hand has drawn the tattered blind
Of dark; in gloom the great cloud-curtained room
  Sleeps: and slowly ardours leave the mind.

Toronto. JOHN DALE.

AD ASTRA

As the fleet train into the dark moves on,
  We catch from village street and hamlet near
The flash of lights, no sooner seen than gone,
  Which ever backward rush in wild career.
But, high above, the sentinels of night
  With steady stride pace on as fast as we,—
Orion, Taurus, and the planets bright,
  Yea, all the myriad of the Galaxy.
So in life's course, whate'er may be our lot,
  Earth's fatuous fires will lure and disappear;
While the high lights of truth will fail us not,
  But on our darkness shine divinely clear.
Scorn, then, ye pilgrims, error's mocking rays,
  And journey safe 'neath Wisdom's beacon-blaze.

—J. E. Wetherell in *Canadian Bookman.*

THE SUMMER SKY

By A. Vibert Douglas

THERE are many who love the restful quiet of a summer evening and are wont to wander forth to watch the last rays of the setting sun and the soft after-glow which gradually fades away leaving a star-studded sky. But how few, comparatively, can point out more than two or three constellations or name the half dozen brightest stars which shine forth from the summer sky! "The study of the heavens," said Sir Robt. Ball, "of boundless interest and of exquisite beauty, leads to the contemplation of grand phenomena in Nature and great achievements of human genius."

The natural starting point in a survey of the heavens is Polaris. This giant star, of absolute magnitude —3.0, is so far distant from our little Solar System that it has only an apparent magnitude of 2.1. It might perhaps be explained that the apparent magnitude of a star is measured on a logarithmic scale of brightness, the 6th magnitude being fixed traditionally and each magnitude above that (namely 5, 4, 3, 2, 1, 0, —1, —2, etc.) indicating approximately two and a half times more light. The classification is done both visually and by photometric means. The absolute magnitude of a star can only be ascertained if it's distance be known. By convention the scale of absolute magnitudes is formed by calculating what would be the apparent magnitude of the star if its distance from the Sun were 10 parsecs, the parsec being a unit of distance defined as that distance which corresponds to a parallactic angle of one second. The parallax of a star is the angle subtended at the star by the radius of the earth's orbit. Since the distance from the earth to the sun is known with great precision, and the angle of parallax for a star can be obtained very accurately by methods similar to those used in land surveying or by a spectroscopic method, highly developed in the last few years, it becomes a simple trigonometrical computation to ascertain the distance of the star. A parsec is approximately

equivalent to the distance traversed by a ray of light travelling for three years at a speed of 186,000 miles per second.

The altitude of Polaris, or its angular distance above the horizon, is the measure of the latitude of the place where the observer is stationed. In the vicinity of London, Eng., this angle is 51°, at Montreal 46°.

Two well-known constellations lie one on either side of Polaris —Ursa Major and Cassiopeia—the former known as the Great Bear, the Dipper or the Plough, and the latter as the W. The esries of bright stars, more or less equispaced, under and around the end of the W, known popularly as Cassiopeia's Guards, form parts of two interesting constellations. Those under the W belong to Andromeda while the next two with two others behind them, forming a great square, are in Pegasus, the Flying Horse.

In the mythology of the ancients, Cassiopeia was the beautiful wife of Cepheus, King of Ethiopia, and Andromeda was their daughter, who, to appease the wrath of Neptune, was chained to a rock to be devoured by a great monster, this awful fate being averted by her rescuer, Perseus, whose wife she afterwards became.

The constellation of Perseus lies too low on the north horizon to be well seen in summer, but in the winter sky it is almost at the zenith and is interesting because it contains the remarkable variable star, Algol. Better placed at this season is Cepheus which lies just above Cassiopeia towards the zenith. King Cepheus, one of the renowned Argonauts, who under the leadership of Jason sailed from Greece to Colchis to bring home the Golden Fleece, was supposed to have been changed into a constellation at his death.

Turning now to the southern or southwestern sky, the brightest object, far exceeding all the fixed stars, is the planet Jupiter. Fourth but largest child of our parent sun, he sweeps around his great orbit in about 12 years, while his motion relative to that of the earth in her orbit makes him seem to move gradually backward or forward amongst certain of the constellations.

Of the fixed stars the brightest in the summer sky is Arcturus, well up in the west. Its apparent magnitude is 0.2 but it is com-

paratively near our sun and its absolute magnitude is only 1.2. The group of smaller stars about it form with it the constellation of Bootes, the Herdsman.

Low in the south is a very beautiful group looking like a giant rocket bursting forth its stars: this is Scorpio, supposed to be the scorpion which Diana sent to sting to death the giant Orion who had offended her. Orion, not visible in summer, is the chief glory of the winter heavens. Antares is the brightest star of Scorpio and its immensity and distance can be judged from the figures, absolute magnitude —2.7 and apparent magnitude 1.2.

Very high in the east and almost as bright as Arcturus is Vega, the gem of the constellation Lyra, the Harp from which Orpheus drew forth his strains of all-compelling melody. A line joining this star to Arcturus passes first through the constellation of Hercules and then through Corona. It is interesting to note that it is towards a point in the vicinity of Hercules that our Solar System appears to be moving. This point, termed the Apex of the Sun's Way, gives the direction of motion of our sun relative to the controid of all the known stars. One of the "great achievements of human genius," surely, was the approximate location of this point by Sir Wm. Herschel towards the close of the 18th century, from his observations of the movements of only seven stars. One of the main objects of modern investigators has been to determine the motions of some thousands of the stars, so that the Apex is now known with what is probably a fair degree of precision.

Not far from Vega towards the north-east is another bright star, Deneb, in the group known as Cygnus, the Swan. It lies in the Milky Way distinguishable as a cross with it's head, Deneb, towards Cassiopeia. There is a double star of historic interest in this constellation known as 61 Cygni. In the years 1837-39 the great mathematician and astronomer, Bessel, observed this pair of stars and determined their distance from the sun with a precision never attained before his time. For many years it was thought that, with the single exception of Alpha Centauri, visible as a 0.3 magnitude star in the southern hemisphere, these stars were our sun's nearest

neighbours but modern measurements have revealed three other stars to be slightly less distant than 61 Cygni.

Below Vega and Deneb in the south-east is another bright star, Altair, in the constelation of Aquila, the Eagle. Mythology tells of Merops, King of the Island of Cos, who was transformed into an eagle and set among the constellations.

Two other bright stars must be mentioned though both lie too near the horizon to give their full brillance: Spica low in the south-west and Capella low in the north. Spica, in the constellation of Virgo, is an important star in navigation, its distance (angular) from the moon being used in one of the ways in which a mariner may determine his longitude. The ancient poets sing of the Golden Age when Astraea, the virgin Goddess of Justice, dwelt among men; and of the succeeding age of wickedness when she wearied of mankind and, returning to heaven, was placed among the constellations as the Virgin holdiing in her hand the Scales of Justice.

Capella, brightest star in Auriga, with an apparent magnitude of 0.7, lies almost in a straight line with Polaris and Vega, its nearest easterly neighbour being Perseus. It is in the winter sky that Capella shines forth with greatest beauty, being the highest in the sky of that marvellous group of bright stars—Castor, Pollux, Procyon, Sirius, Betelgeuse, Rigel and Aldebaran—now for a season withdrawn from our view.

The summer sky differs in many respects from the winter sky but who shall say that the glory of the one exceeds the glory of the other, for each presents one aspect of an unfathomable universe whose "boundless interest and exquisite beauty" refresh the mind and soul of the thoughtful star-lover, and doubly reward the persistent investigator by yielding up one by one some of the secrets of time and space?

McGill University,
Montreal, Que.

THE 1924 TRANSIT OF MERCURY

By Albert R. Hassard

ALTHOUGH the early part of Wednesday, the 7th of May, 1924, looked unfavourable for viewing the transit of Mercury, the afternoon became all that the most eager votary of astronomical science could desire. I shall give my own meagre experiences in connection with the event.

A four-inch refractor was used in the observations. Thinking that the transit might be capable of being projected on a screen, I secured a circular piece of cardboard, about 14 inches in diameter, cut a hole in its centre, and fastened it to the telescope, so that the image of the sun projected on another piece of card would have as much contrast as possible.

By using the telescope in this manner, I totally lost the earlier part, or commencement, of the transit. Although I had found the point where the planet was likely to make its entrance on the sun, I could see nothing, although I watched, not only that point, but all parts of the circumference of the sun's image, very carefully for some minutes both before the time the transit was due to commence, and also afterwards. I do not understand why I could not see the planet. Having seen nothing for nearly ten minutes I altered my method, and affixed a "sun-glass" to the eye piece. I now saw the planet well upon the disc of the sun, near the eastern limb—a little to the right of the bottom of the image as viewed in the inverting refractor. The planet was there, a tiny black spot upon the disc of the sun, which was otherwise apparently unmarked, except by a double sun spot above and to the left in the telescopic field of view.

The planet kept creepng forward in an upward and left hand direction during the period it was visible, or until about 8.05, daylight saving time, when a dense cloud drew over the sun, and by that time the orb had sunk behind the chimneys and roofs which girded the western horizon.

The transit was witnessed by members of my own family, and some other friends, to all of whom it was an object of distinct interest.

I tried to locate the planet with the help of a field glass magnifying about four and one-half diameters, but could not detect it. When using the field glass, I looked through only one of its tubes, holding the coloured sun-glass before its eye-piece while making the observation.

I also made the same experiment with the finder of the telescope, which magnified, possibly, eight or nine diameters. Very faintly could I observe through it the planet.

After about 7.30 p.m., when the strength of the sun was noticeably failing, I viewed its disc without the aid of a coloured glass. Sometimes the sun was struggling through clouds—these began to make their appearance at about this time, but some of them were faint and filmy—and at other times the sun was free and bright in the late afternoon sky. There was no difficulty in viewing the transit thus, without any coloured glass to reduce the brightness of the sun's rays at all. The sun then shone with a lustrous splendour, and on its face was the tiny black dot, the image of the planet. The sun's rays during the last half hour of the phenomenon were just such as did not inconvenience the eye by either their intensity of glare, or their heat.

Perhaps the most striking feature of the transit was the sudden revelation of the the exceeding smallness of the planet when on the sun's broad face. I had expected a much larger object, and was disappointed in finding that the visitor to the sun was so manifestly tiny. Most of the time I used a mangifying power of sixty to one hundred diameters. Even with such optical aid the spectacle was none too striking. Still it was an event not to be missed, and was welcome to those who love to contemplate the mysteries of the skies.

THE APPLICATIONS OF MODERN PHYSICS TO ASTRONOMY

(*Continued from last issue*)

IV. The Analysis of Light

The Spectroscope

We have now discussed how big, how heavy and how hot the stars are merely by examining the star's light taken as a whole. If now we take the light apart or analyse it we can increase our knowledge of the stars enormously. The instrument by which this is done is the spectroscope, and it is by far the most important of astronomical instruments. The action of this instrument is briefly as follows. Light passes through a narrow slit and then through a lens which renders it parallel. This parallel light passes through a prism which causes light of each colour, having a different frequency of vibration and consequently a different wave length, to be deviated from its path by a different amount. The light, after passing through the prism, passes through another lens to a photographic plate, where it produces images of the slit, one in each colour. When examined with such an instrument different bodies give different patterns or spectra. The study and interpretation of these patterns constitutes spectrum analysis.

Substances Present in the Sun

Investigation has shown that dense gases, glowing liquids and incandescent solids give a spectrum which is a band of light, red at one end and blue at the other and continuous throughout its whole length. Rarefied gases, on the other hand, give off different specific kinds of light and their spectra are patterns of bright lines, the pattern depending on the kind of gas and being characteristic of it and it alone. If compounds are present in the source the pattern is much more complicated, being composed of numerous bands. But, whether an element or a compound, each substance gives a definite pattern; and, if ten such spectra were superposed, each substance could be identified. In addition to these facts,

there is the additional one that gases absorb the same kinds of light as they give off. Let us apply this to the sun. The sun is a dense body which by itself would produce a continuous spectrum. But it is surrounded by an atmosphere of metallic vapours which absorb the same kinds of light which they give off and which produce a number of dark lines on a continuous background. A comparison of the spectrum of iron and that of the sun shows that practically every iron line matches a dark line in the solar spectrum. Thus we have learned that iron exists in the sun. By comparing the spectra of the terrestrial elements with the solar spectrum we now know that about 40 or 45 of the known chemical elements are present in the sun. This leads us to believe that the constitution of the sun is probably similar to that of the earth. This belief is strengthened by the fact that predominant lines in the solar spectrum are those of the most common metals on the earth, one exception to this being the metal potassium, which is weak in the sun.

Are Non-metallic Elements in the Sun?

An examination of the solar spectrum shows that the hydrogen lines are strong, the oxygen lines are weak, and the lines of non-metallic elements are absent. Are we justified in saying that this proves the absence of non-metallic elements in the sun? The answer to this has been found only recently, aided by modern knowledge of how light gets out of the sun. When we examine the spectrum of hydrogen we find few lines, while the spectrum of iron contains thousands. The spectra of some elements show regular recognizable groups of lines, while in the spectra of others the lines appear to be scattered about indiscriminately. A knowledge of the mechanism by which these spectra are produced is necessary in order that we may interpret properly the spectra of the sun and of the stars.

The origin of all light is the atom. In solids and liquids the atoms are so close together that they cannot act freely, and so every process by which light is produced occurs, giving light of each wave-length. In gases, however, the atoms are far apart and can act independently, thus producing specific kinds of light or light of definite wave-lengths. In order to understand how these

specific kinds of light are produced we must know something about the constitution of the body producing them—the atom.

The Structure of the Atom

The first step in the investigation of the mechanism of the atom was made by Sir J. J. Thomson, who succeeded in obtaining from the atom a far smaller and lighter body which carried an electrical charge. This body is the electron. Millikan later developed a method of determining the charge on an electron, and this enables us to determine the exact weight of the individual atom from the charge per unit mass. As a result of these and other investigations the prevailing belief now is that the atom is composed of a minute centre or nucleus bearing a positive charge, with electrons revolving around it in orbits, each electron having an electrical charge of -1 (minus one), while the nucleus has a positive charge equal to the total negative charge of the electrons. In the case of lithium there are three electrons, two revolving in small orbits and one in a large orbit. Beryllium has two electrons revolving in small orbits and two in large, while carbon has two electrons revolving in small orbits and four in large orbits. In the case of lithium, the one electron in the large orbit may be easily removed, giving lithium a combining valency of 1. Beryllium, with two electrons in large orbits, has a valency of 2, while carbon, having four electrons in large orbits, has a valency of 4. From this it appears that the electrons in the large orbits are easily removed, while the system of nucleus and two electrons in small orbits is quite stable. This combination gives us the atom of helium and accounts for the inertness of that gas. This brief description of the simpler atoms shows that, in general, the atom is a tremendously complex system.

How the Atom Produces Light—Bohr's Theory

Modern ideas of how light is produced by the atom are due to Bohr, who explained the action of the hydrogen atom in giving off light. In the first place, the hydrogen atom consists of one electron which revolves around the nucleus. This electron must travel in certain orbits and may not travel in others, and the orbits in which the electron may revolve are such that the areas swept out by the electron in unit time are multiples of a certain constant quantity.

This is expressed differently by saying that the radii of the orbits are in the proportion,

$$1^2 : 2^2 : 3^2 : 4^2 : \ . \ . \ . \text{ etc.}$$

The evidence in favour of this theory of the atom is mainly the ability of Bohr, by these assumptions, to explain the nature of the hydrogen spectrum. In order to get rid of energy an electron may move from one orbit to another and back again. This energy is produced in the form of light, and, moreover, the relation of the amount of energy given off to the wave-length of the light produced is expressed by the equation

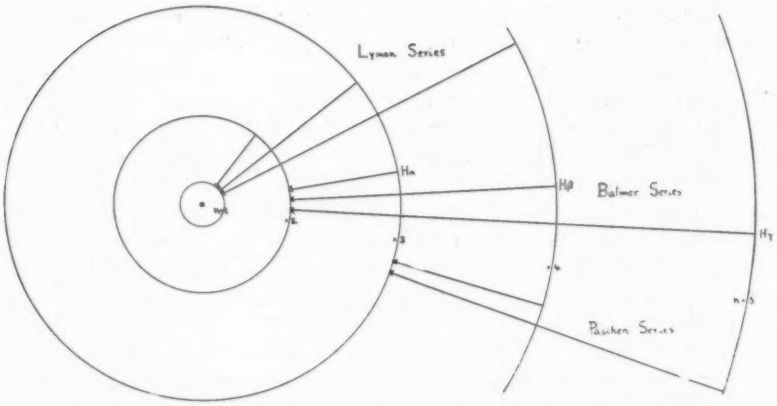

Fig. 11—Diagram of the hydrogen atom and its orbits. When an electron moves from one orbit to another, energy in the form of light is produced

$$h\,\nu = \epsilon,$$

where ϵ = energy, ν = frequency, and h = quantum constant.

Now the work done in taking an electron to infinity is inversely proportional to the radius of the orbit (Fig. 11). Thus the

Work done in removing an electron from 1st orbit to infinity = hN
" " " " " " " 2nd " " " = $\frac{1}{4}hN$
" " " " " " " 3rd " " " = $\frac{1}{9}hN$
etc. etc.

Hence the work done in removing an electron from the first orbit to the third orbit is

$$hN-\tfrac{1}{9}hN=hN(1-\tfrac{1}{9}),$$

and therefore the frequency of the light produced is

$$\nu=N(1-\tfrac{1}{9});$$

and similarly for other orbits. Consequently if this theory is to hold, the hydrogen atom should give off light of frequencies given by these values. Now the hydrogen lines are produced at exactly the theoretical places and, as a result, the theory has been accepted.

The Helium Atom: Ionization

In the case of more complicated atoms satisfactory formulae cannot be developed, however, except in the case of helium under certain conditions. If we apply enough energy to the helium atom to remove one of its electrons completely, and then to move the other one into one of the larger orbits, we shall have only one electron, and thus the frequencies of the emitted light can be calculated after the same manner as for hydrogen. In the case of helium, however, the value of N will be different and consequently the helium lines will not coincide with the hydrogen lines.

The process of removing one electron from an atom, as we did to confirm Bohr's theory in the case of helium, is known as *ionization*. If, then, we remove an electron from an atom, the ionized atom which we obtain will be positively charged and will give an entirely different spectrum from its ordinary spectrum, for it is really a different substance. Ionized gas is easily produced in the electric spark and perhaps to some degree in the arc. Lines due to ionized gas, then, are prominent in spark spectra and faint or absent in arc spectra. These lines are known as *enhanced* lines. In the spectra of the whiter and hotter stars these enhanced lines appear, while the arc lines appear in the redder and cooler stars.

The Atoms of Lead and Silicon

Let us for a moment consider the lead atom, which theoretically has 82 electrons. It should therefore be possible to remove 82 separate electrons, thereby producing 82 distinct lead spectra. It is quite a simple matter to remove the first electron, but to remove the second requires greater energy. This produces vibrations of

high frequency, the lines appearing in the ultra-violet part of the spectrum. The spectra produced by the removal of the third and fourth electrons are in the extreme ultra-violet and the radiation is stopped by air. In order to obtain these spectra the entire apparatus must be in a vacuum.

In the case of silicon we have four electrons and therefore four spectra. The first spectrum, when all electrons are present, is found in the electric arc and appears in the solar spectrum. The second, which is found in the electric spark, is produced when the first electron has been removed and the second is in process of removal. It appears in stars like Sirius. The third type, produced after the second electron has been removed, is found in the spark in which greater energy per atom is applied. It appears in the spectra of Orion type stars. The fourth type, produced when three electrons have been removed, appears only in the very hottest stars.

Application to the Sun

Having analysed the spectrum in this manner we are able to use our information for various laboratory and astronomical purposes.

Let us now apply these principles to the case of the stars and, in particular, to that of the nearest star, the sun. There are two different spectra ordinarily obtained from the sun, that of the surface in general and that of the sun spots. We know that these spots are relatively cool because they are redder. If we examine the two types of spectra we will notice that in the spot-spectrum many lines are weakened while some are strengthened. To interpret these differences we have only to remember that the temperature of the spots is lower than the mean solar temperature and that, consequently, there will be fewer atoms from which electrons have been removed, that is, fewer ionized atoms. This should result in a weakening of the enhanced lines. An examination of the spectra shows this always to be the case. If we consider magnesium, which is hard to ionize, we should expect that there would be little or no change in the two spectra. In the case of sodium we have an easily ionized metal. Therefore at the high solar temperature most of the atoms will have lost the first electron and the lines will appear

strongest in the ultra-violet portion of the spectrum, which is inaccessible to us on account of the absorption of the earth's atmosphere. In the spots, however, the temperature is lower and consequently there should be more neutral atoms present, resulting in a strengthening of the sodium lines in the spot-spectrum. A similar method of reasoning can be applied in the case of other metals, and, in each case, the predictions are borne out by facts.

The Flash Spectrum

Let us now consider what is known as the flash spectrum of the sun. This is obtained at the time of an eclipse by the use of a prismatic camera, the exposure being made during the few seconds when the moon's disc has completely covered the photosphere but has not yet covered the atmosphere of metallic vapour surrounding the sun. The lines in this case will be crescents, the brightest being those due to radiations excited by the most frequent changes of the electrons within the atom. From a spectrum of this type we are able to determine the height above the sun's surface at which each line is produced. We find that the enhanced lines are strongest and are observed higher up in the solar atmosphere than the arc lines. Now, in all probability the temperature of the sun's atmosphere is fairly constant throughout, but the pressure will naturally be much less at the top than at the bottom.

If the temperature is constant the same number of electrons will be removed in the same time, but if the pressure is low the chance of an atom regaining an electron is less than if the pressure is high. Thus there will be more ionized atoms in the upper regions of the solar atmosphere, pressure rather than temperature being the cause; and, since there are more ionized atoms, the enhanced lines will be stronger and the arc lines weaker than in the lower region. Thus a discussion of the manner in which lines are produced by changes in the energy state of the atom enables us to interpret the spectra of the sun.

Sun-spots are Magnetic Vortices

When we examine the spectrum of a sun-spot we find that in some cases the lines are widened, while in other cases they are doubled or tripled. This is known as the Zeeman effect. When

light is produced in a magnetic field it is polarized, or the electrons vibrate in one direction in preference to another. By the use of a Nicol prism we are able to determine the direction of polarization, and finally we are able to measure the magnetic field of a sun-spot. The strength of this field is about one-third that used in the largest generators and is maintained over the immense area of the spots. It is also found that adjacent spots have opposite polarity, and that, if in the northern hemisphere the leading spot has its magnetic field upward, the field of the leading spot in the southern hemisphere will be directed downward. These facts lead us to believe that the spots are vortices in the sun's surface.

The sun-spots, then, are ascending tornadoes in the solar atmosphere. As the gases rise they expand and thus become cooler; and, due to the continued upward flow of gas, remain at a temperature of about 2000 degrees less than the rest of the sun, for months at a time in some cases. The whirl of the ascending gas accounts, too, for the polarity of the field. It is believed that the leading and following spots are connected far below the surface in a manner similar to the two vortices caused by drawing an oar through water. The opposite polarity of leading spots in the two hemispheres is caused by their opposite direction of rotation. That they should have this opposite direction of rotation is only to be expected, since the sun rotates on its axis and since the rotation of the earth causes cyclones in the two hemispheres to rotate in different directions. Sun-spots have a period of about eleven years and, at the beginning of each new cycle, the polarity of the spots is reversed, remaining opposite in each hemisphere. At present, theory has not been able to account for this satisfactorily, but a certain amount of support is given to the idea that each cycle is a kind of unit.

V. The Analysis of Stellar Atmospheres

Six Main Types of Stellar Spectra

In order to classify the spectra of the stars it will be necessary for us to obtain the spectra of a great number of stars. These are most conveniently obtained by means of the prismatic camera, which, besides enabling us to obtain many spectra in a short time,

gives us spectra in which hundreds of lines show. If we examine these spectra we shall notice at once that there are very few spectral types in comparison with the number of spectra. This work of classifying stellar spectra has been carried on extensively at Harvard College Observatory, where spectra of about a quarter of a million stars have been examined.

Of these over 99½ per cent. fall into six main groups, arbitrarily lettered B, A, F, G, K, M. Each of these classes contains approximately the same number of stars and changes into the succeeding class by imperceptible degrees, thus forming a steady continuous sequence. In order to describe the spectrum of a star (say) half way from B to A, the symbol B5 is used, while if it is eight-tenths from B to A the symbol B8 is employed. This classification by means of a letter and a number takes in about all the differences which can be noticed. This series moreover is a linear series, there being only one way of proceeding from B to M, and that through a steady set of changes. Consequently whatever is back of these changes must be changes in one major condition of a star, because, if there were changes in two independent conditions there would be more than one way of proceeding from one end of the series to the other.

Temperature the Key to Stellar Type

This one major condition is believed to be temperature. The continuous background of the spectrum gives the change in colour index, which can be measured and the temperature computed. If we plot a curve between colour index and spectral class (Fig. 12) we obtain a curve which is quite smooth. Thus the stars of any one class are similar in colour, so much so in fact that the colour is of value in determining the spectral class of a star which is too faint to make a photograph of its spectrum possible. The method adopted in the study of these faint stars is to photograph them in ordinary light and then with a yellow screen in front of the lens. Enough stars have been checked in this way to show that there is a close agreement between these results and the actual values.

The Slit Spectroscope

Now the prismatic camera is not the only way of photographing stellar spectra, for the slit spectroscope may be used. This gives

much better definition and also permits the introduction of a comparison spectrum on each side of the stellar spectrum, enabling us to measure the wave length of a line to within two in one million parts. This accuracy of measurement also makes it possible for us to measure the shift of a line due to the Doppler effect—the shift

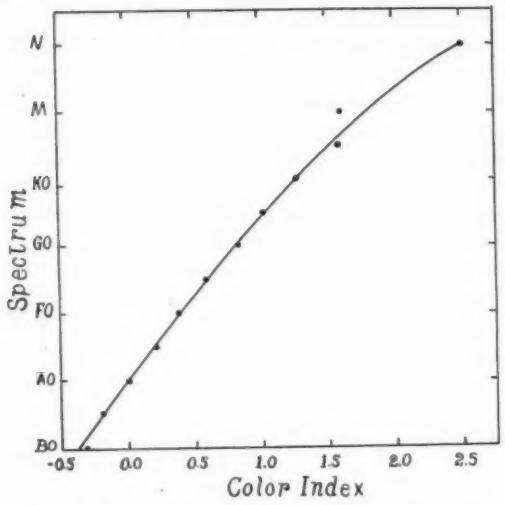

Fig. 12—Curve showing relation between colour index and spectral class

due to relative motion in the line of sight. Spectra obtained in this manner, however, require much longer exposures than in the case of the prismatic camera.

The following is a brief description of the various spectral types.

Type	Characteristics of Spectra
B	Lines of ionized H, He, O, and N present.
A	H lines stronger, He lines weaker, lines of ionized metals present.
F	H lines weaker, lines of ionized metals stronger, lines of ionized Ca present, lines of neutral atoms appear.
G	H lines inconspicuous, enhanced lines begin to weaken, arc lines stronger.
K	Arc lines of metals numerous and close together, spark lines faded out in general, although spark lines of calcium and titanium present, "ultimate" lines of metals appear.
M	Flame lines strongest; bands, indicating compounds, chiefly titanium oxide, appear.

Since bands appear in the spectra of M type stars, indicating the presence of compounds, we are led to believe that the stars of this type are at ordinary laboratory temperatures and that the K type stars are above these temperatures. This is in agreement with the results obtained by the colour index method and therefore the lower end of our temperature scale, at least, is accurate.

Where are the Metals and the Gases?

The question now arises as to where the metals are in B type stars and the gases in those of type K. Are we to believe that some stars are made of permanent gases, some of permanent metals and some of permanent compounds? If this is so, then a regular change from one type to the next would be impossible. And even if we are to believe this is so in the case of ordinary stars, how are we to believe it in the case of eclipsing variable stars, in which the components are physically connected, often separated by hardly more than their own diameter, and yet in which one star may be of type A while the other may be of type K? In this case it is incredible that all the metals should be in one half of the body which divided to form the double star and all the gases should be in the other. The explanation seems to be that there is some condition which prevents the gaseous spectra from appearing in K type stars and metallic spectra from appearing in those of type A. This whole question is explained quite satisfactorily by the theory of ionization.

Application of the Ionization Theory

Let us consider for a moment the case of titanium oxide. This is decomposed at a high temperature. As the temperature is raised there will be more metal and less oxide present, but at any temperature there will exist a state of equilibrium between the oxide and the metal. Similarly in the case of the atom, as the temperature is raised the atoms gradually lose their electrons and become ionized. At some temperature 100 per cent. of the atoms are neutral. As the temperature is raised, first (say) 90 per cent. will be neutral and 10 per cent. ionized, then 80 per cent. will be neutral and 20 per cent. ionized, until finally, when the temperature is sufficiently high, 100 per cent. of the atoms will be ionized.

Let us apply this to the case of the stars. At low temperatures compounds are not dissociated and stars have characteristic banded spectra. As the temperature rises the compounds dissociate and the bands disappear, while the arc lines of the metals appear. With a further increase of temperature the enhanced lines of the easily ionized elements appear and the arc lines commence to fade out. Still higher temperatures cause the enhanced lines to become maximum and then to fade out. At higher temperatures the arc lines have practically disappeared, while the hydrogen lines are strong, hydrogen being difficult to ionize. Very high temperatures cause the lines of ionized helium to appear between the hydrogen lines while in the O type stars the temperature is so high that even the lines of ionized helium disappear.

Thus we see the importance of modern spectral theory in explaining the sequence of stellar spectra.

Spectra of Faint Red Stars

At the end of our sequence we have faint red stars. Most of these exhibit the characteristic bands of titanium oxide and are placed in class M. Others however show bands which are sharp towards the red and faint towards the violet end of the spectrum. These bands are due to compounds of carbon and stars of this type are placed in two classes, R and N, forming a side branch of the main series. Still other stars exhibit the bands of zirconium oxide and are placed in class S, still another branch. Thus the complete arrangement of stellar spectra is

$$\begin{array}{l} \qquad\qquad\qquad\qquad\quad /\text{R—N} \\ \text{O—B—A—F—G—K—M} \\ \qquad\qquad\qquad\qquad\quad \backslash\text{S} \end{array}$$

Thus it is seen that above class K there is only one sequence, but below it, where the temperature is low enough to permit of the existence of compounds, there are several sequences. This is readily explained, for we can see that if the temperature is sufficiently high to prevent the formation of compounds, the relative quantities of each element are unimportant, little difference being caused by either twice or half as much of an element being present. At temperatures which permit the formation of compounds, however, a difference in the relative quantities of the elements causes

a great difference in the spectrum of a star. If in the atmosphere of a star there is little oxygen, carbon, because of its great affinity for oxygen, will take most of it, and the other elements will not be oxidised. Hence the spectrum will be characterized by the bands of carbon compounds. If, on the other hand, there is plenty of oxygen in the stellar atmosphere, then the carbon will be completely oxidised and the titanium will also be oxidised. Thus bands of titanium oxide will characterize the spectra of stars whose atmospheres are rich in oxygen. In the case of the S type stars, in which the bands of zirconium oxide appear, the theory has not yet been developed, but will probably be somewhat of the same nature. Thus we have seen that M type stars have an oxidising atmosphere while stars of types R and N have reducing atmospheres. In general then in the case of high temperatures the properties of matter are simple, but in the case of low temperature stars they are complicated. The low temperature stars, in which compounds first appear, are then the probable beginning of individual evolution. As the temperatures become lower and lower, liquid and finally solid formations are possible, which permits of the existence of life.

Some Peculiar Spectra

These additional spectra, the R, N and S types, account for more than 999 stars in 1000. But there are stars whose spectra are not accounted for. Many of these appear to be of type B except that emission lines of hydrogen are present. If there is a large amount of light emitted in the ultra violet portion of the spectrum, there may be sufficient energy absorbed by the hydrogen atoms to move the electron from orbit 1 to orbit 3. If now the electron falls back to orbit 2 the red hydrogen line will be emitted and, since the star emits relatively faint red light, it will appear bright by contrast. Most of these spectra appear to be ordinary spectra having bright lines superposed, the presence of the bright lines being accounted for in a manner similar to the above.

One peculiar type of spectrum must also be noted, the M type which also shows the bright lines of hydrogen. In every such case the star is found to be a variable. As the star becomes fainter the bands disappear and bright lines, which have been identified

as low temperature metallic lines, appear. Some of these are iron lines. Now in the electric furnace there are many iron lines but in the star there are relatively few. Consequently there is a temptation to say that the lines in the spectrum of the star are those of an unknown substance. But at the lowest possible temperatures at which a spectrum can be produced most of the iron lines disappear and only a few remain. These remaining lines coincide exactly with the lines in the spectrum of the star and are the lines caused by the transition from the very lowest energy state of iron.

Giants and Dwarfs; Spectroscopic Parallax

So far we have only discussed the effects of temperature on stellar spectra. We must now consider the effects of pressure, for we have seen that, with a constant temperature, higher pressure will cause a weakening of the enhanced lines.

Let us consider the connection between brightness and spectrum* (Fig. 13). In the case of type G stars their brightness is about the same as that of the sun. M stars, however, are either much brighter or much fainter than the sun, there being no stars of this type of intermediate brightness. This gives rise to the names of "giant" and "dwarf" stars. These names are suggested by their brightness, but a moment's thought will show that these stars are actually *giant* and *dwarf* in size as well. Now the giants and dwarfs of the same type have differences. Lines which are faint in one will be intense in the other, and lines intense in one will be faint in the other. Moreover stars which are intermediate in brightness show lines which are intermediate in intensity. If then we plot the estimated intensity of a line against absolute magnitude we obtain a fairly smooth curve. If we do this for all the lines which show this change, we shall get a number of such curves. If now we take the spectrum of a star whose absolute magnitude is unknown we can, by estimating the brightness of the various lines, determine the absolute magnitude, which in turn enables us to determine the distance. These distances are known as

*A more complete diagram illustrating tnis is given by Curtis and is reproduced in this JOURNAL, vol. 16, p. 213, 1922.—H.F.B.

spectroscopic parallaxes, from the method by which they were obtained.†

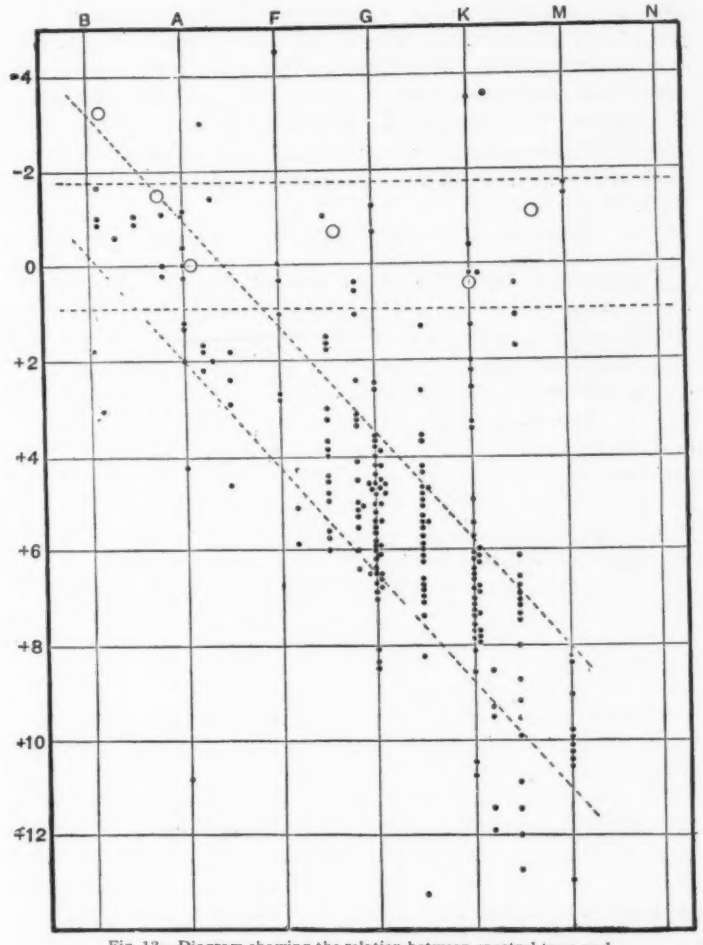

Fig. 13—Diagram showing the relation between spectral type and absolute magnitude (or brightness)

†See the extensive and valuable paper by Young and Harper in this JOURNAL, vol. 18, p. 9, 1924.—H.F.B.

When tested on forty or fifty stars of known parallax the spectroscopic parallaxes were found to be in excellent agreement, the average error being about 25 per cent. This error would be too great for large parallaxes, but in the case of small parallaxes this error is smaller than that of other methods. This method is applicable to all stars whose spectra can be photographed, although its best application is to stars of types from F to K. Its great advantage lies in the fact that the labour involved is less than in other methods, while the accuracy obtained is greater for the distant stars.

Pressure, Spectroscopic Parallax, Ionization

The cause of the change in intensity of the lines, on which the theory of spectroscopic parallaxes is based, is the difference in pressure existing in the stars, the theory of ionization satisfactorily explainng the change. Let us consider two M type stars at the same temperature whose brightnesses bear the ratio of 100,000:1 and whose masses consequently bear a ratio of about 10: 1. In general it will be seen that stars of large diameters will have low density and pressure, while small stars will have high density and pressure. On account of these things the large star will encourage ionization by making it harder for an atom to regain an electron once it has lost it, while the small star will tend to discourage it. Consequently in the giant star the enhanced lines will be strong while in the dwarf the arc lines will be strong. In general then this describes the condition, but there are a few details which require more attention.

Pressures in the Star and in the Sun

We have said that small stars have high pressures. Our next step is to obtain some idea of what these pressures are, and, in order to do this, we study the nearest star, the sun. Now in the laboratory, if increased pressure is applied to a luminous gas, the spectral lines become wider and more fuzzy and, at the same time, their centres shift a little toward the red end of the spectrum. At high pressure each atom exerts a greater attraction on its neighbours and thus less energy has to be applied in order to move an electron into an outer orbit and consequently, if we were to observe one atom from the lot, we should see a sharp line shifted

a little to the red. But actually we observe millions of atoms which gives a number of sharp lines together, producing the broad and fuzzy appearance of the lines. It has been shown that lines which are shifted to the red in the arc are shifted less to the red in the sun. This leads us to believe that the portion of the sun's atmosphere producing the lines is under a pressure of about one and one half pounds per square inch, with an error of about one and one half pounds each way. That is, that the pressure is less than three pounds per square inch. Moreover the lines which are fuzzy in the arc and which are sharp in vacuo are also sharp in the sun, which gives us still another reason for believing that the lines in the solar spectrum are produced at low pressure. Again, we know, from the relative intensity of the calcium lines, that this element is more than half ionized in the sun. In order that this may be possible on the basis of our theory a low pressure is necessary. These three considerations give the average pressure in the sun's atmosphere at which lines are produced to be about 1/1000th of the pressure of the earth's atmosphere. This is confirmed by a simple laboratory experiment. If we put some common salt in the electric arc we obtain sharp absorption similar to that in the sun. But the absorption in the arc is caused by a layer of gas not more than one quarter of an inch thick at atmospheric pressure. Consequently for the same effect to be produced in the great thickness of solar atmosphere it must be at a very low pressure. Thus the rather surprising fact that all solar lines are produced in regions of very low pressure is clearly proved.

Why the Sun's Limb is Sharp

We know that the solar gases are subject to a gravitation force 27 times the gravity of the earth and that therefore an atmosphere such as the earth's would exert a pressure of over 400 pounds per square inch. We know, too, that no known substance could condense at all on account of the high solar temperature, which rises as we approach the centre of the sun. Now how can a gas containing no solid or liquid particles present a sharp outline and also the great detail shown in sun spots? On account of the great gravity of the sun the pressure should increase rapidly downward, but the high temperature would tend to counteract this, making the distance in which the pressure is doubled about the same as

that in the earth's atmosphere, namely, five miles. Thus we rapidly pass from a region of very rare gas to a region of very dense gas. Consequently as we pass inward we shall, well within a distance of 100 miles, pass from the region in which lines are produced to a region where the scattering of light is so great that no light from behind will be able to pass through. Now a distance of 100 miles corresponds to ¼ of a second of arc. Consequently even in the best telescopes the image will appear sharp.

In gas at high pressure the free electrons are numerous and are constantly colliding with atoms, as a result of which the energy of light is changed into energy of motion, or heat. Consequently a large number of free electrons cause the gas to become opaque. Since about half the atoms in the sun are ionized, one particle in three will be an electron. From this we can calculate the number of collisions and therefore the amount of energy changed to heat. Now this absorbing power depends on the number of collisions. With twice the density there will be twice the number of collisions and thus twice the absorption. In the upper regions where the pressure is 1/100,000th that of the earth's atmosphere light must traverse thousands of miles to produce appreciable absorption, while at a short distance below the pressure will be only one-tenth atmospheric and complete absorption will take place in less than one mile. Thus in a distance of fifty miles we pass from a region transparent for thousands of miles to a region opaque in a few miles. Consequently the sun presents to us a spherical surface, the photosphere or "light sphere".

On this basis practically all existing knowledge is reconciled. Moreover this theory is general and therefore applicable to the stars also, except perhaps in the case of low temperature, low ionization, dwarf stars. In these, possibly, the lines may be fuzzy, while in the giant stars of low density, low gravity and low pressure above the sphere of opacity there are sharp lines.

We can now see why the sun spots show such great detail. The hot and cool gases in the extreme outer layers shine brightly and darkly, while the deeper portions under the spot, the neck of the ascending tornado, cannot be seen.

Thus modern theory turns a series of apparently discordant details into a beautifully related sequence.

VI. The Constitution and Evolution of the Stars

Changes in an Isolated Mass of Gas

If we plot absolute magnitude against stellar type (see Fig. 13), we find that the stars appear to fall into two groups, one group being about 100 times brighter than the sun and composed of stars of all types, and another group forming a continuous sequence from the bright white stars to the faint red ones.

The red stars are undoubtedly cooler than the others and must have, therefore, a smaller surface brightness. A bright red star is bright either because of large surface brightness or because of large diameter. The first of these reasons has been shown to be impossible, and hence the bright red stars must have large diameters and the faint red stars must have small diameters. In addition to this, we have already shown that the bright red stars are of low density, and that the faint red ones are of high density.

If, now, we arrange the stars according to their density, we shall obtain a steady continuous sequence from the red giants through the yellow giants to the red dwarfs. In order to account for this progression let us consider what would happen in a mass of rarefied gas isolated in space. In the first place this mass would be denser, and, therefore, hotter inside, as a result of which heat would flow outward and be lost. In order to keep up the supply, some other form of energy must continually be changing into heat. According to the Helmholtz contraction theory, this other form of energy is gravitational energy, the gas slowly contracting, thus changing gravitational energy into heat, which slowly leaks to the outside of the mass and is lost.

Change of Temperature as Gas Contracts

Let us now determine how the temperature of the gas will change as the gas contracts. We know that, according to the ordinary gas law,

$$P = R\rho T,$$

where P = pressure, R = gas constant, ρ = density of the gas, and T = absolute temperature.

If now the body contracts to half its original size, assuming that the density at corresponding points always bears the same rela-

tion to the average density, the density will now be eight times its original value. Now the pressure at a point is due to the weight of the column of matter above that point. Since the star has shrunk to half its original size, the same amount of matter will be in a column whose area is one quarter of the original area, and whose centre of gravity is only half as far away. Consequently the pressure is now four times as great on an area one quarter the original size. Hence the pressure per unit area has increased to sixteen times what it was before contraction. Placing these values in the above equation, assuming that originally

$$P=1 \text{ and } \rho=1,$$

we have that, before contraction,

$$1=R\,.\,1\,.\,T,$$

whence

$$T=1/R;$$

and that, after contraction,

$$16=R\,.\,8\,.\,T,$$

whence

$$T=2/R.$$

Hence, as the star contracts to half its size, its temperature is doubled. This, however, only applies to a rare gas, for which the gas laws hold. As the gas becomes denser it becomes increasingly difficult to compress, and, consequently, at the same temperature, a greater pressure than that required by the gas law is necessary. This means that in a dense gas an increase in pressure will produce a smaller rise in temperature than it would in a rare gas. As it becomes more difficult to compress the gas, the increase in temperature will become less and less, until finally the temperature will not increase as the gas is compressed, after which it will be necessary for the gas to cool in order to be compressed.

Increasing and then Decreasing Brightness

As a star contracts its area decreases but, due to the rise in temperature, the amount of light per unit area increases. These two changes tend to counteract each other and so, as the star becomes hotter its apparent brightness remains about the same until the "white" stage is reached. After this the star becomes smaller with rapidly diminishing brightness.

A check on this theory is given by the actual densities of the stars. It has already been shown that the large stars have low densities. According to the theory, too, the stars having the high st temperatures should have such densities that the gas laws just begin to cease being applicable. This density has been estimated to be about one-tenth that of water. Since the stars of the highest temperatures have densities from one-half to one-fiftieth that of water, the actual densities may be said to agree with the density required if the theory is to hold.

We also know that B type stars are quite massive, having, on the average, three times the mass of the A type stars. According to our theory the temperature will be proportional to the mass and so the more massive a star is, the higher will be its maximum temperature. This also explains why the very hottest stars, those of type O, are the most massive of all.

Why Giant Stars are more Massive

The next thing which must be explained is why the giant stars are more massive on the average than the dwarfs. This is caused mostly by the manner in which the stars are selected, the giants being chosen by their apparent brightness and the dwarfs by their proper motions. Now stars whose brightness is 100 times the brightness of the sun, that is giant stars, can be seen with the naked eye up to a distance of 500 light years, while dwarf stars, whose brightness is only about one one-hundredth of that of the sun can be seen only up to a distance of 5 light years. Consequently the ratio of the space in which we select giant stars to the space in which dwarf stars are selected is the ratio of 500^3 to 5^3 or 1,000,000 to 1. So that, even if we suppose that there are 10,000 dwarfs to every giant, the probability is one 100 to 1 that a giant is chosen. Thus the method of selection of giant stars favours actual brightness and, therefore, the massive stars, while the proper motion method of selection of dwarf stars favours those of small mass, since it is believed that those of small mass move faster.

Stages in the Life of a Star

Thus a star begins its life as a huge mass of rarefied gas which contracts, begins to glow, becoming red, and as its temperature

rises, white or yellow. After this it still contracts, becoming cooler and redder, until it finally becomes smaller than the sun and has a low surface temperature, ultimately ceasing to emit light.

This theory of stellar evolution is the one most generally accepted. While qualitatively it appears to be quite simple, quantitatively it presents some little difficulty.

Temperature and Pressure within a Star

Let us consider the general expression for the temperature and pressure within a star of mass M and radius a. At any point the pressure $P = xP_o$,

where P_o = the pressure if the star were homogeneous;
and the density

$$\rho = y\rho_o,$$

where ρ_o = the density if the star were homogeneous.

Now the mass $M = 4/3\ \pi\rho_o a^3$,

whence $$\rho_o = \frac{3}{4\pi} \cdot \frac{M}{a^3}.$$

At the centre of the star

$$P = \tfrac{1}{2} g_1 \rho_o a,$$

where g_1 = gravity at the surface $= GM/a^2$,
and G = gravitational constant.
If now we substitute the values of g_1 and ρ in the expression for P we have, at the centre of the star,

$$P = \frac{3}{8\pi} \cdot \frac{GM^2}{a^4}.$$

According to the gas laws

$$T = \frac{m}{R} \cdot \frac{P}{\rho},$$

where m = mean molecular weight;
whence

$$T = \frac{m}{R} \cdot \frac{x}{y} \cdot \frac{GM}{2a},$$

where R = gas constant $= 8.32 \times 10^7$,
and G = gravitational constant $= 6.66 \times 10^{-8}$.

On substituting these values of R and G, we have

$$T = 3.98 \times 10^{-16} \cdot m \cdot \frac{x}{y} \cdot \frac{M}{a}.$$

Matter at a Temperature of a Million Degrees

Thus it is seen that, if we can safely apply the gas laws to matter at stellar temperatures, the temperature at the centre of the stars must be expressed in millions of degrees. Now, to determine whether we can apply our laws of the properties of matter at high temperatures, suitable experiments can be performed by shooting electrons at atoms, the speed of the electrons being controlled by the electrical potential applied. If in these experiments we knock one of the inner electrons from an atom an outer electron falls in to take its place, producing X-rays. To do this a potential of at least 14,000 volts is necessary, the effect of this potential being the same as the effect of a temperature of one hundred million degrees. This shows that, at this temperature, the atom is stable and so we can still talk of the properties of matter. Moreover, the constants involved are very general and there is no reason to suppose that they would change at these temperatures.

The actual results however did not agree with the theory until the pressure of radiation was taken into account. The relation between the radiation pressure P_r, and the temperature T, is given by

$$P_r = \tfrac{1}{3} a T^4,$$

where a = energy per c.c. $= 7.6 \times 10^{-15}$ ergs.

Moreover, this relation depends on the quantum theory, a very general theory which is not expected to fall down at high temperatures. In the larger stars the radiation pressure becomes an appreciable quantity and we must not fail to take it into account in our theory.

(*To be continued*)

REVIEW OF PUBLICATIONS

Die Veraenderlichen Sterne. Herausgegben von Johann Georg Hagen, S. J., and Johann Stein, S. J., II Band: *Mathematisch-physikalischer Teil,* von Johann Stein, S. J., 4to, 404 pages, Freiburg im Br., Herder. Price $7.

This is the second and last volume of the authors' monumental work on variable stars. In the first volume Father Hagen dealt with the historical-technical branch of the subject, while in the present volume Father Stein gives the physical explanations of the variable stars.

After an extended catalogue of the literature on variable stars, there follow four sections. The first comprises four chapters and treats of new stars. The second, in three chapters, deals with long-period variables. The third has four chapters devoted to the "Blinksterne" or wink-stars, of which Delta Cephei and Zeta Geminorum are examples. The fourth section has eight chapters and deals with eclipsing variables, such as Algol.

The mathematical discussions of the various theories are rigid and complete, and the work will be of great and permanent value.

C. A. C.

History of the Royal Astronomical Society 1820-1920, edited by J. L. E. Dreyer and H. H. Turner with chapters by them and by R. A. Sampson, E. H. Grove-Hills, H. F. Newall and H. P. Hollis. 258 pages, $6\frac{1}{4} \times 9\frac{1}{2}$ inches, with 12 plates. London, published by the Society and sold by Wheldon and Wesley, 1923. Price 20s.

The idea of compiling this *History* was started some time before the 100th anniversary of the founding of the Society, but through unforeseen delays it was not published until the end of last year.

During this first century of the Society's existence there were many notable episodes in the development of astronomy in England,

and this volume gives an intimate account of the men who played the leading parts in them. There are also references to foreign astronomers who visited the Society or sent communications to it. Indeed, all through the book are numerous personal incidents which make the history of astronomy live for us.

There is not space here for an adequate review of this work, and it is hoped that a fuller account of it may be printed later during the year. It need only be said that it is of great value and interest, and the best wish for the Society is that its second century may be as good as its first. C.A.C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

Honour for Director S. A. Mitchell

At Convocation on May 7, Queen's University conferred the degree of Doctor of Laws on S. A. Mitchell, M.A., Ph.D., professor of astronomy at the University of Virginia and director of the Leander McCormick Observatory on account of his "international eminence as an astronomer." Dr. Mitchell was born in Kingston, received his early education from the public schools and Collegiate Institute of Kingston and graduated from Queen's in 1894.

Professor Mitchell is a recognized authority on eclipses of the sun. His book entitled "Eclipses of the Sun" published by the Columbia University Press last September has been so well liked by the public that a second edition has become necessary. The revised edition will include a discussion of the 1923 eclipse and the additions to the Einstein theory that have appeared since the first edition went to press. The new edition will appear in November.

During the past year Dr. Mitchell has been elected a fellow of the American Academy of Arts and Sciences and a member of the American Philosophical Society.

The Elliptical Solar Halo

Mr. Edgar W. Woolard, of the U.S. Weather Bureau, Washington, D.C., writes:—

The April number of the Journal of the Royal Astronomical Society of Canada has just come to my attention, in which, on page 182, you have a note regarding a solar halo observed by Rev. N. R. D. Sinclair, with a reference to a similar halo observed in 1904 by Mr. A. F. Hunter.

Mr. Hunter's observation that the halo appeared to him as an elliptical halo with a circular one within and tangent to it, is correct.

The inner halo is the common 22° halo, and the elliptical outer halo is formed by the merging, at this elevation of the sun, of the upper and lower tangent arcs of the 22° halo. The Reverend Mr. Sinclair makes an error, which is very commonly made, in ascribing the phenomenon to two intersecting circles eccentrically situated with respect to the sun.

The arc extending out toward the east is an arc of the parhelic circle; the rainbow arc bending away from the sun is one of the infralateral tangent arcs of the 46° halo.

Under separate cover I am sending you a reprint of an article on halos which I published sometime ago in *Popular Astronomy* for December, 1920. I am now at work on an exhaustive monograph on the subject.

Observations of Mercury

The Editor was pleased to receive the following notes from his young friend, Mr. David Rosebrugh, of Niagara Falls, Ont.:—

I possess a fairly good pair of field glasses, objective 39 mm., power 6. On the afternoon of May 7 by their use, and with the aid of a rather dense photographic negative folded double as a dark glass, I was able to follow the transit of Mercury from 5 p.m. until 6.30. At 5 o'clock it had just nicely entered the disc, while at 6.30 it was of course about one-quarter of the way across. I found it much easier to see the planet when the sun was partially obscured by light clouds, as irradiation rendered it nearly invisible, especially after it was well on the sun's disc.

My impression is that Mercury is much more readily visible at its unfavourable elongations than is represented by the Handbook. Thus at the elongations of January 13, 1923, and December 27, 1923, it was readily visible to the naked eye, and in the case of the December elongation I picked it up by eye at first glance, about 5 o'clock, as I recollect it, on December 24. It was, of course, just skimming the house-tops at the time, and would be visible in a city only from an open space.

ROTATION PERIOD OF VENUS

Among the numerous problems being investigated at the Mount Wilson Observatory is whether Venus has a short period of rotation, as was believed for many years, or a much longer one, which was first announced by Schiaparelli and now is favoured by most astronomers. In the Annual Report of the Director of the Observatory for 1923, an account of work by St. John and Nicholson on Venus is given.

Differential measures at the limb and terminator can be used to determine the rotation of the planet. Measures of this character give a small negative value for the equatorial velocity of Venus, with a probable error of the same order. It is in this case assumed that the plane of the planet's equator is in the plane of its orbit. A similar investigation made some years ago by Slipher at the Lowell Observatory also gave a small negative value for the equatorial velocity. This would suggest that the planet rotates in an opposite direction to that of the earth and Mars, which is very improbable. The negative values are probably due to errors of observation. The conclusion reached is that the chances are about ten to one that the period is longer than 20 days.

Prof. W. H. Pickering has suggested that the equator of Venus is nearly perpendicular to the plane of its orbit, but the Mt. Wilson results are decidedly against this.

Amateur Telescope Construction

In a personal letter Mr. H. C. B. Forsyth, of Clagary, Alberta, informs me that he had almost completed a 12-inch mirror for a reflecting telescope, this being the seventh mirror made by him. I hope to publish a photograph of the telescope when finished. To anyone with a mechanical turn the construction of a telescope is a fascinating occupation. There is great satisfaction in building one's own instrument and the striving after perfection in the form of the mirror is certainly a fine mental training.

I receive many inquiries for telescopes for amateurs, and believe that a good 2½ or 3 inch refractor with a convenient rigid mounting would have a large sale. It is desirable that a 3-inch instrument should not cost more than $100. To anyone who can supply such instruments I should be glad to refer all inquiries.

C. A. C.

MEETINGS OF THE SOCIETY

At London

February 8.—The meeting was held in Room 4, University of Western Ontario, Dr. H. R. Kingston presiding.

Dr. Kingston gave a short address, explaining how to use the table on page 11 of the Handbook, to find the time of sunrise and sunset at London, Ontario, or any other place desired. He also referred to the transit of Mercury over the sun's disk on May 7, 1924.

The Secretary, Dr. White, followed with an address on the planet Mars. By blackboard diagrams the relative position of Mars in the solar system was shown, and Mars and the earth were compared as regards size, mass, toration, etc. It was pointed out that Mars is the first of the superior planets, being about 1½ times as far from the sun as is the earth. Because of the eccentricity of the planet's orbit its distances from the sun and the earth vary greatly from time to time. Its greatest distance from the earth is about 234 million miles and at opposition near perhelion is about 35 million miles from the earth. Mars rotates on its axis every 24 hours 37m. 22s., as we count time, and its synodic period is a little more than two of our years.

Lantern slides were used to show the most striking features of the surface of Mars as seen through a large telescope, or as given by photographs. A description was given of the polar caps, the canals, the oases, the regions which show various shades of orange and yellow and the patches of bluish-grey and green.

It was pointed out that the polar caps are thought to be snow, that they change with the season. The blue-grey or green patches were called seas, but are now looked upon as due to vegetation, and the orange and yellow regions are thought to be deserts. Some astronomers believe that the canals point to an elaborate irrigation system.

The question of the habitability of Mars was then considered and arguments were presented to show that it is probable that Mars has an atmosphere, a surface temperature and other conditions that would make life possible.

E. T. WHITE, *Secretary-Treasurer.*

The regular monthly meeting was held on March 14th, at 8.15 p.m., in Room 4, University of Western Ontario, Dr. H. R. Kingston presiding.

Dr. Kingston gave an illustrated address on "Ancient Clocks." He pointed out that in the early days there was much opposition to new discoveries in Science but in the last sixty years much progress has been made.

Astronomy in giving to the world a means of measuring time has made a very valuable contribution. Time is measured by marking off equal intervals—we have a sidereal day, an apparent solar day and a mean solar day.

The ancients marked the passing of time by reference to some outstanding event—some comet, a meteor shower, a new star, an eclipse of the sun or of the moon. In Egypt Sirius, rising directly East and setting directly West in June, presaged the overflowing of the Nile.

The recurring of equidistant events, such as the new moon, gives us our month. The revolution of the stars gives us sidereal time. The days of the week were named for the seven moving objects in the sky, viz., Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn.

The need arose for small divisions of time. For this purpose the ancients used the sun dial and the water clock. Slides were used to show the construction of these. Galileo discovered the use of the pendulum for clocks and this soon replaced the older forms and introduced the modern clock.

E. T. WHITE,
Secretary-Treasurer.

At Toronto

March 25,—The regular meeting of the Society was held in the Physics Building of the University at 8 p.m., the 2nd Vice-President, Mr. A. F. Hunter, in the chair.

Mr. A. F. Miller reported additional observations of the relative brightness of Betelegeuze and Rigel.

Dr. Chant explained the heliocentric chart of the planets and its use to determine the phase of Venus.

Mr. S. C. Brown reported observations of Venus and Saturn, describing their appearance by means of diagrams.

The constellation talk was given by Mr. A. Kennedy, who discussed the constellation Gemini, showing where to find it between Sirius and Ursa Major. He spoke of its age and origin, giving Biblical references to it. He also described the star Castor, which is a double, each component of which is a spectroscopic binary.

The paper of the evening was given by Mr. Wm. Gore, who described a new theory of gravitation and matter. By this theory, which supposes the ether to be made up of columnar vortices in three coordinate directions, he explained the mechanical means by which one body attracts another, a thing which none of the generally accepted theories do. He also pointed out that, by this theory, it was not necessary to depart from the fundamental idea that time, space and matter are independent.

After the questions of several members concerning the theory had been answered, the meeting adjourned.

April 8,—The meeting was held in the Physics Building of the University at 8 p.m., the 2nd Vice-President, Mr. A. F. Hunter, in the chair.

An invitation from the University of Toronto and the Royal Canadian Institute requesting the presence of delegates from the Society to the International Mathematical Congress to be held in Toronto from the 11th to the 16th of August, 1924, was read. On motion of Dr. Chant, seconded by Mr. W. E. W. Jackson, this matter was referred to Council.

The following were elected members of the Society:—

Earle G. Linsley, Director of Chabot Observatory, Oakland, Cal.
E. A. Stevens, 94 Cowan Avenue, Toronto.

An observation of an occultation of Aldebaran, and naked eye observations of Venus in bright sunlight were reported by the Recorder.

Dr. Chant spoke of the elongation of Venus and Mercury, and explained using the celestial sphere, why these elongations were exceptionally good for observation.

Mr. A. F. Miller spoke of the constellation Gemini, reporting observations made in past years.

Mr. S. C. Brown gave a talk on the constellation Canis Major, describing its position with respect to Orion and Canis Minor. He also described the appearance of the "dog" and spoke of the double stars in this constellation.

The address of the evening was given by Sir Frederick Stupart, F.R.S.C., who chose as his subject "The Weather of the past winter." This address was not merely a description of the weather of the past winter, but was rather a general account of the factors influencing weather conditions, both locally and throughout the earth, together with a statement of the problems still confronting the meteorologist. The address was well illustrated with lantern slides showing the general distribution of pressure over the earth and particularly that over the North American continent, and the effect of the distribution on the weather.

April 22,—The meeting was held in the Physics Building of the University at 8 p.m., the 2nd Vice-President, Mr. A. F. Hunter, in the chair.

An invitation from the Franklin Institute to the Society to send a representative to the Centenary Celebration was read and referred to Council.

The following were elected members of the Society:—

G. M. Bryce, 3 Bowden Ave., Toronto.

A. W. Entwistle, Knox College, Toronto.

Mr. A. F. Miller reported a small group of sun-spots to be visible. Mr. A. F. Hunter reported an observation of a mirage which caused the moon to appear to be twice its ordinary diameter. Mr. Gore reported observations of Mercury.

Mr. A. F. Miller gave a talk on the constellation Scorpio; this is the eighth sign but, due to precession, the ninth constellation of the Zodiac. It is the best constellation to observe with a small telescope and has had more novae appear in it than any other constellation.

Mr. A. R. Hassard, B.C.L., gave the paper of the evening on "The approaching Transit of Mercury". These transits occur within two or three days of May 7 and November 8. By means of diagrams the path of Mercury across the sun's disk was shown for this and the other transits of this century.

After expressions of appreciation from several members, the meeting was adjourned.

H. F. BALMER,
Recorder.

The Royal Astronomical Society of Canada

(OFFICERS FOR 1924—REVISED TO MARCH 1ST, 1924)

Honorary President—HON. G. H. FERGUSON, K.C., B.A., LL.D., Minister of Education for Ontario.
President—R. M. STEWART, M.A., Ottawa.
First Vice-President—WM. BRUCE, J.P., Hamilton.
Second Vice-President—A. F. HUNTER, M.A., Toronto.
General Secretary—F. T. STANFORD, Toronto.
General Treasurer—H. W. BARKER, Toronto.
Recorder—H. F. BALMER, B.A.
Librarian—PROF. C. A. CHANT.
Curator—ROBERT S. DUNCAN.

Council—MGR. C. P. CHOQUETTE, M.A., LIC.SCS., Montreal; J. B. FRASER, M.D., Toronto; R. A. GRAY, B.A., Toronto; A. R. HASSARD, B.C.L., Toronto; J. H. HORNING, M.A., Toronto; PROF. JOHN MATHESON, M.A., Kingston; SIR JOSEPH POPE, K.C.M.G., Ottawa; JOHN SATTERLY, M.A., D.Sc., Toronto; DR. W. M. WUNDER, Toronto; and Past Presidents: JOHN A. PATERSON, M.A., K.C.; SIR FREDERIC STUPART, F.R.S.C.; A. T. DELURY, M.A.; LOUIS B. STEWART, D.T.S.; ALBERT D. WATSON, M.D.; ALLAN F. MILLER; J. S. PLASKETT, B.A., D.Sc., F.R.S.; J. R. COLLINS; W. E. W. JACKSON, M.A.; and the Presiding Officer of each Centre as follows: R. J. MCDIARMID, Ph.D., Ottawa; REV. FATHER T. W. MORTON, B.Sc., Winnipeg; W. E. HARPER, M.A., Victoria, B.C.; JUSTICE E. E. HOWARD, Montreal; H. R. KINGSTON, M.A., Ph.D., London, Ont., and the Officers as above.

OTTAWA CENTRE

President—R. J. MCDIARMID, Ph.D. *Vice-President*—C. R. COUTLEE, C.E.
Secretary—A. H. MILLER, M.A. *Treasurer*—W. S. MCCLENAHAN, B.A.

Council—T. L. TANTON, Ph.D.; E. A. HODGSON, M.A.; THOMAS DONOHER, and Past Presidents: R. M. STEWART, M.A.; F. A. MCDIARMID, M.A.; J. J. MCARTHUR, D.L.S., and R. E. DELURY, Ph.D.

MONTREAL CENTRE

Honorary President—MGR. C. P. CHOQUETTE, M.A., LIC.SCS.
President—HON. JUSTICE E. EDWIN HOWARD.
1st Vice-President—MR. H. E. S. ASBURY.
2nd Vice-President—PROF. A. H. S. GILLSON.
Secretary-Treasurer—MR. A. W. STRONG.
Recorder—REV. W. T. B. CROMBIE, M.A., B.D.
Assistant Recorder—MISS A. V. DOUGLAS.

Council—PROF. A. S. EVE, D.Sc., C.B.E.; MR. GEO. SAMPLE; MR. JULIAN C. SMITH; MR. E. W. PASK; MISS M. H. ELLICOTT.

LONDON CENTRE

President—H. R. KINGSTON, M.A., Ph.D.
Vice-President—MISS GRACE BLACKBURN.
Secretary-Treasurer—E. T. WHITE, B.A., D.Paed.

Council—REV. R. J. BOWEN, F.R.G.S.; MRS. S. R. MOORE; H. B. HUNTER; J. C. MIDDLETON; W. A. MCKENZIE.

WINNIPEG CENTRE

President—REV. T. W. MORTON, B.Sc.
Vice-President—MRS. E. L. TAYLOR.
Curator—DR. L. A. H. WARREN.
Secretary-Treasurer—MR. H. B. ALLAN.

Council—DR. N. B. MACLEAN; MRS. S. C. NORRIS; MR. D. P. MORSE, C.E.; DR. N. R. WILSON; MR. J. H. KOLB; MR. CECIL ROY.

VICTORIA CENTRE

Honorary President—DR. J. S. PLASKETT, F.R.S.
President—MR. J. DUFF.
Vice-President—MR. F. C. GREEN.
Treasurer—MR. J. P. HIBBEN.
Secretary—MR. F. MOORE.

Executive Committee—MESSRS. P. H. ELLIOTT; H. CAMERON; R. G. MILLER; W. H. CHRISTIE.

Auditor—MR. H. H. PLASKETT.